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ABSTRACT

This publication is intended to serve as a guide for teachers introducing the metric system to elementary and secondary school students. Suggestions are based upon the premise that students learn best when totally involved in activities using the metric system, with few comparisons to our traditional English system of measurement. The booklet includes: a statement of the need for metric instruction, a summary of metric terminology, a list of advantages of the metric system, a set of relevant behavioral objectives, and some specific teaching suggestions. References and a list of addresses from which to obtain additional metric teaching materials are included. (CR)

BULLETIN NO. 1

A GUIDE TO TEACHING THE METRIC SYSTEM

Division of Science and Technology
Bureau of Curriculum Services
Pennsylvania Department of Education
1974

Commonwealth of Pennsylvania
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Subject: Instruction in the Metric System

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To: Chief School Administrators
Intermediate Unit Executive Directors
Diocesan Superintendents
Administrators of Other Nonpuplic Schools

From: Donald M. Carroll, Jr.
Commissioner for Basic Education

On September 13, 1974 the State Board of Education established regulations providing for instruction in the metric system of measurement:

Regulations

5.32 Metric System (For the Elementary School)

The concepts of measurement shall be taught using the units of the metric and English Systems co-equally in the activities of science and mathematics in each school year as part of the planned courses of these subjects as appropriate. Such instruction shall be included in the learning activities of all subjects and be designed to develop skills for the use of the metric system in everyday life.

5.77 Metric System (For the Secondary School)

The concepts of measurement in all subjects shall be taught emphasizing the use of the metric system and referring to the English System only as special requirements demand its use. Specialized courses such as science and mathematics shall utilize whatever measuring system is consistent with the specialized measuring activities of the discipline. Instruction in measurement shall be concerned with those measurement skills and units used in everyday life, except for specialized courses where extensive measuring activities are required, and shall be concerned with the understanding and use of the systems of measurement.

For aid in implementing a program for metric education, please contact:

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PURPOSE

This publication is intended to serve as a guide to help teachers introduce the metric system. It is meant only as a nucleus of ideas upon which you can build to achieve a suitable program for classroom use. You will probably come up with your own ideas which are unique. As you do, please let us know about them so we can include some in a later edition of this guide.

The metric system should be introduced to primary, intermediate, and secondary students through the same introductory and developmental concepts, however, the techniques can be varied according to level.

We encourage you to have your classes "think metric"--to become totally involved with the use of the metric system with little or no conversions or comparisons with the imperial (English) system of measurements. The best way to do this is to get students actually using the metric system.

INTRODUCTION

Instant communications and international trade make the worldwide adoption of standard units of measurement a necessity. All but a very few nations have committed themselves to the International System which includes the metric system of weights and measures.[1] The United States is the only major nation which has not yet made this change, but will probably do so in the near future. We presently use the English or Imperial System of Weights and Measures, the same system we used when we were an English colony.

Measurement affects our daily lives in countless ways. We refer to measurement units when we buy shoes or lumber, when we travel from one place to another, weigh ourselves, make an appointment for a certain time of day, or listen to weather forecasts.

The metric system is a decimal system, which is a common system of numeration. In the United States we use a decimal system for our money: a dollar is worth ten dimes, and a dime is worth ten cents.

In the metric system the unit of length is the metre; the unit of mass is the gram, and the unit of capacity is the litre. Temperatures are measured in degrees Celsius.

Measurements in the metric system usually combine a prefix with the base unit. The following chart indicates those metric prefixes as they relate to the base units.

	1000	100	10	1	$\frac{1}{10}$	$\frac{1}{100}$	$\frac{1}{1000}$
Decimal System	thousands	hundreds	tens	ones	tenths	hundredths	thousandths
Metric System Symbols	kilo* (k)	hecto (h)	deka (da)	unit	deci (d)	centi* (c)	milli (m)

*These are the commonly used prefixes.

The following brief description produced by the National Bureau of Standards will help you understand the metric system.

All You Will Need to Know About Metric

(For Your Everyday Life)

10

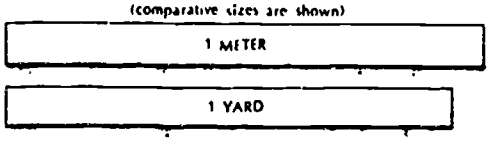
Metric is based on Decimal system

The metric system is simple to learn. For use in your everyday life you will need to know only ten units. You will also need to get used to a few new temperatures. Of course, there are other units which most persons will not need to learn. There are even some metric units with which you are already familiar: those for time and electricity are the same as you use now.

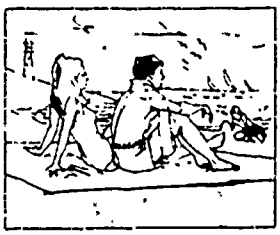
BASIC UNITS

METER: a little longer than a yard (about 1.1 yards)
LITER: a little larger than a quart (about 1.06 quarts)
GRAM: about the weight of a paper clip

(comparative sizes are shown)



25 DEGREES FAHRENHEIT

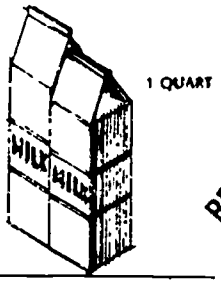


25 DEGREES CELSIUS

COMMON PREFIXES
(to be used with basic units)

Milli: one-thousandth (0.001)
Centi: one-hundredth (0.01)
Kilo: one-thousand times (1000)

For example:
1000 millimeters = 1 meter
100 centimeters = 1 meter
1000 meters = 1 kilometer

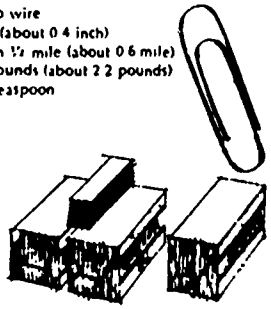


OTHER COMMONLY USED UNITS

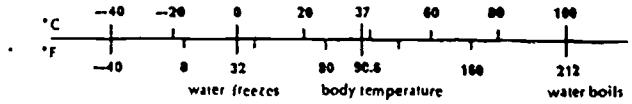
Millimeter:	0.001 meter	diameter of paper clip wire
Centimeter:	0.01 meter	width of a paper clip (about 0.4 inch)
Kilometer:	1000 meters	somewhat further than ½ mile (about 0.6 mile)
Kilogram:	1000 grams	a little more than 2 pounds (about 2.2 pounds)
Milliliter:	0.001 liter	five of them make a teaspoon

OTHER USEFUL UNITS

Hectare: about 2½ acres
Tonne: about one ton



TEMPERATURE
degrees Celsius are used



For more information, write to: Metric Information Office, National Bureau of Standards
Washington, D.C. 20234

[1]SI (International System) spellings for metre, litre and gram are used consistently throughout this document. The one exception to this rule appears on the page reprinted from the National Bureau of Standards publication. This page predates the international agreement on SI spelling.

The metric system has many advantages over the English system. Several of these advantages appeared in The Arithmetic Teacher of April 1973. For your information, they are:

COMMONLY LISTED ADVANTAGES OF THE METRIC SYSTEM

1. The metric system is a simple, logically planned system. Its decimal basis conforms to our numeration system.

2. The metre, which establishes the basis for the entire system, is always reproducible from natural phenomena and, therefore, is immune to destruction; it is international in character and well-suited for precision work. The coordination of measures of length, area, volume and mass, combined with decimalization, facilitates computations.

3. Once the system of prefixes has been learned, the uniformity in names for all types of measures makes for greater simplicity and ease in changing to more convenient-sized units for specific purposes.

4. Although many of the claims of the amount of time that can be saved in learning fractions are probably exaggerated, less competence in manipulation of common fractions would be required of many students, and some restructuring of time spent on such computation might be profitably accomplished. Ultimately, when only the metric system would be taught, time could be saved in learning of conversion units (1 ft. = 12 in., 1 yd. = 3 ft., 1 rd. = 16½ ft., 1 mi. = 5280 ft., and so on) and in the learning of a second new system for use in science classes.

5. For ordinary work, familiarity with the metre, gram and litre would be sufficient. However, for the engineer and the scientist, the new International System of Units (SI), based on the metric units, eliminates conversion problems in calculations with derived units. That is, although power is universally defined as work per unit time, it is variously expressed in Btu/sec., therms/day, ft-lb/hr., horsepower, calories/sec., watts, and so on. The use of two different terms, kilogram and newton, for units of mass and force respectively, eliminates much of the confusion students have concerning these concepts.

6. Greater participation of the United States in the setting of international engineering standards would be possible since the metric system is the universal language of measure. Exports, foreign trade, and competition with other nations will depend more and more on production under metric standards.

7. A common measurement language that is used by scientists, engineers, and industrial workers would improve communication and reduce barriers between different sectors of society.

8. The necessity of conversion would offer fringe benefits. During the adjustment to the new measurements, there would be opportunities to eliminate superfluous varieties in sizes of products, parts and containers, and to make additional worthwhile changes in engineering standards, construction codes, and products design.

RECOMMENDED COMPETENCIES FOR STUDENTS LEAVING COMMONWEALTH SCHOOLS

As a result of their school experiences, the public school graduate will be able to:

1. Demonstrate an understanding of the approximate nature of measurement.
2. Select an appropriate nonstandard unit and measure a given quantity.
3. Select the appropriate standard unit in the metric system.
4. Demonstrate the proper use of measuring devices using metric units.
5. Know and use the proper symbols for the metric units.
6. Estimate lengths, area, masses and temperatures in metric units and verify by measurement.
7. Demonstrate the decimal relationship of the place value names of the metric system.
8. Demonstrate the relationship between linear, area and volume measurements.
9. Use a Celsius thermometer to determine temperatures and be familiar with the common reference points.

HOW DO YOU TEACH METRIC?

Teaching metric is really no different from teaching any other system of measurement. To a child first learning to measure, the units used make little difference. Confusion may result when two different sets of units are used and conversions between the two sets are made.

The metric system is simpler to use than the English system for computational purposes because it uses the decimal relationship between units. Fractions, the bane of teaching the English system, are seldom required when the metric system is used.

These items may be purchased from supply houses. References for sources of materials are given in the appendix.

Many common materials may be used for making measurements in the metric system: lengths of string or paper, coins, paper clips, and Cuisenaire rods.

EXPERIENCES IN METRIC EDUCATION

The following curriculum guidelines are in sequence under topics. However, it is not necessary for the student to master one topic before the next is introduced. It is probably wise to repeat some earlier activities from time to time to reinforce measurement concepts.

DIRECT COMPARISON OF QUANTITIES

There are many opportunities to compare quantities. For example:

1. Which student is tallest?
2. Does a soda can hold as much liquid as a cafeteria milk carton?
3. Which is heavier, your pencil or your shoe?

Students should be given daily opportunities to compare quantities.

INDIRECT COMPARISON OF QUANTITIES

Measurement becomes necessary when two quantities which are to be compared cannot be "brought together" or are so similar that they cannot be compared by observation. Comparisons can be made by using a third object, such as a ruler or a balance. Will this act change the properties of the object being measured? Do the students have the concept of conservation of length and mass?

It is desirable that students be exposed to many activities involving direct and indirect comparisons, which provide the foundation for all measuring activities that follow.

In the following activities, there is no required sequence. Choose the activity most appropriate to the concept being developed. However, ordering and comparisons should introduce each concept.

LINEAR MEASURE

1. The student will sort objects into sets of relative lengths by means of superposition.

   1.1 Cut soda straws into various lengths being certain that at least two or more of each length are equal. Give these to the students and ask them to separate the straw segments into piles of straws of equal length. Compare lengths by placing the straws side by side.

2. The students will order objects from shortest to longest.

   2.1 Have the students take one straw segment from each pile and order the segments from the shortest to the longest straw.

   2.2 Have the students cut a length of yarn or string into various lengths. Order the segments.

   2.3 Provide a worksheet which will reinforce the concepts of ordering by length.

3. The students will develop the need for standard units of measurement.

   3.1 Measure with nonstandard units, such as a part of the student's body (the hand or foot). Compare the variance in results due to the differing sizes of the students.

   3.2 Measure with nonstandard units, such as paper clips. Develop the idea that all of the paper clips should be about the same size.

      3.2.1 Develop the idea that the number of units in the measure depends on the length of the object and the size of the units (e.g., three small paper clips or two large ones).

   3.3 Measure with metric units.

      3.3.1 Teach the child what a metric ruler is and how it is used.

         a. A metric ruler or a ruler using any other system is, essentially, a number of standard units laid end to end.

         b. The ruler must be placed along the line to be measured and should be read from the zero point.

         c. The student should learn what unit is being used (i.e., centimetre or metre).

3.3.2 Have the students measure their desk tops, textbooks, or their heights to the nearest whole centimetre. Graph the results.

3.3.3 Using the metre as the unit of measure, measure the classroom or the playground.

3.3.4 Use measuring devices to introduce the millimetre to show its relationship to the centimetre and metre.

3.3.5 Stress discrimination between the appropriate units for use in specified measurement activities.

3.3.6 How far is it to the nearest neighboring town in kilometres?

AREA MEASURE

1. The students will develop the concept of area.

1.1 Develop the meaning of area. Have the students compare areas of surfaces and estimate which is larger. Then measure them to determine which surface is actually larger.

1.2 Develop the idea that area can be measured with the use of a cardboard cutout of a square, rectangle, parallelogram, or other geometric shape.

a. Develop the idea that the units must be equal in size and shape.

b. Develop the idea that the square is the most efficient unit.

1.3 Develop the idea that the square centimetre is a unit.

a. Use square centimetre cardboard cutouts to measure areas.

1.4 Measure with one centimetre transparent grids or centimetre graph paper (See example of cm^2 graph paper in appendix). Have the child place the grid over the figure to be measured and count the squares to determine area.

1.5 Demonstrate the approximate nature of area measurement. For example, an acceptable answer would be "about 17 blocks are needed to cover this figure".

1.6 Develop computational methods and formulas for finding area.

VOLUME AND CAPACITY MEASURE

Although capacity is the term for the quantity of matter which a container can hold and volume is the number of cubic units achieved as a result of computation, these terms may be used interchangeably.

You may wish to use sand instead of water in the activities which follow.

1. The student will compare the volumes of liquids in tall, thin containers and short, wide containers by pouring the same measured volume of liquid into each container.

   1.1 Develop the concept of volume: how much space an object occupies.

   1.2 Visually compare the volumes of two different amounts of the same substance.

   1.3 Using a graduated cylinder or other standard measuring device, pour the same amount of water (or water with a small amount of coloring added to increase visibility) into a short, wide container and into a tall, narrow container. Ask the class which container holds the greatest amount of water. Start a discussion concerning why the tall, thin container seems to hold more liquid than the short, wide container.

2. The students will demonstrate that the volume of a liquid remains constant as the liquid is transferred from one container into another.

   2.1 Measure an exact volume of water. Pour it into the tall, thin container. Then pour it from this container into the short, wide container. Finally, pour it back into the graduated cylinder and determine the volume. If all the liquid has been poured from the containers and none has been spilled, the final volume will be the same as the initial volume.

   2.2 Develop the concept of conservation of volume by pouring an amount of liquid from container to container, using different sizes and shapes of containers.

3. The students will develop the concept of standard units and how they are used to measure volume or capacity.

   3.1 Measure the volume of containers by filling them with objects such as blocks or marbles.

   3.2 Construct a cube of cardboard or paper, measuring one centimetre on each side (the one cm Cuisenaire rods or the Ohaus centicube may be used) to demonstrate the cubic centimetre unit of volume measure.

3.3 Construct a cube of one decimetre on each side from oak tag. Reinforce the cube with masking tape and line it with a plastic bag or plastic wrap. This becomes a litre. Use it to measure various quantities of liquids.

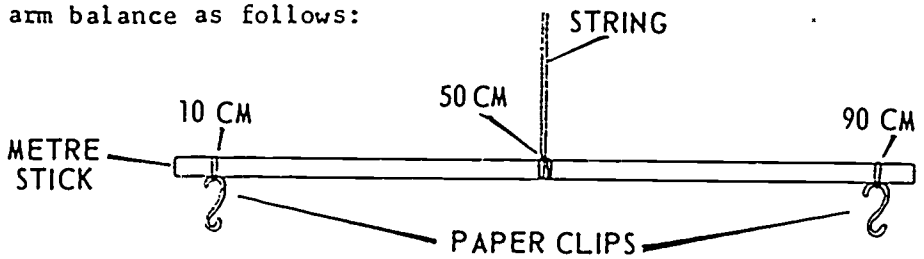
3.4 Ask your industrial arts shop to construct various models of the cubic centimetre, cubic decimetre, and cubic metre.

MASS MEASURE

In the following activities the terms weight and mass will be used interchangeably, since all activities concerning mass will be conducted on the surface of the earth.

1. The students will compare the weights of objects by using an equal arm balance. They will order the objects from lightest to heaviest.

   1.1 If your school does not own a balance, construct an equal arm balance as follows:



   The objects whose weights will be compared may be suspended from the paper clip hooks at opposite ends. Ask the students to order the objects according to weight from the lightest to the heaviest.

2. The students will compare the weights of small objects by determining the number of arbitrary units needed to balance each object on an equal arm balance.

   2.1 Have the students determine the weights of the objects in terms of the number of paper clips or washers needed to balance the object on an equal arm balance. Ask them to order the objects in terms of the number of paper clips used.

3. The students will identify the common metric units of weight (grams, kilograms). Using a balance, they will measure the weight of small objects to the nearest gram and order the objects from lightest to heaviest.

   3.1 Give the students a balance, weights and a number of small objects. Have them weigh the objects to the nearest gram. Ask them to order the objects weighed from lightest to heaviest.

3.2 Ask the students to explain the numerical relationship between the gram and the kilogram.

*In schools where standard weights are not readily available, have the senior high science department provide weights made of sand-filled containers, balls of clay or pieces of metal.

3.3 Ask your industrial arts department to make up sets of weights cut from scrap materials, such as metal rods.

3.4 Have the students use a metric bathroom scale to determine their body weight in kilograms. Graph the results for the class.

TEMPERATURE MEASURE

The Celsius (centigrade) scale is used for most common temperature measurements. Explain the scale and its fixed points, the freezing and boiling points of water.

1. The students will read a Celsius thermometer to determine temperature.

1.1 Have the students determine the outside temperature at a specific time each day for two weeks. Graph the results.

1.2 The students will determine the temperature of containers of warm and cool water to the nearest degree Celsius. Which temperatures are comfortable and which are not?

1.3 Discuss body temperatures and normal room temperature in degrees Celsius.

THE METRIC SYSTEM IN THE TOTAL EDUCATIONAL PROGRAM

Earlier in this publication it was suggested that you teach the metric system as an integral part of learning measurement rather than add an isolated metric unit to your science or mathematics program. Continued exposure to the metric system and its applications to everyday experiences will make the students (and the teacher) more comfortable with the system and its uses. Every subject area contains measurement items which can be stated in metric units. Following are a few suggestions for your use. This list is by no means exhaustive. Many other applications will occur to you as you teach your classes.

1. Prepare a metric road map of your area, indicating all distances in kilometres. (To convert miles to kilometres, multiply the distance in miles by 8/5.)

2. In social studies class, have the students prepare papers or exhibits of civilization's methods of measuring down through the ages.

3. Most dressmakers' patterns give measurements in both the metric and English systems. Have your students determine their body size in metric measurements.

4. Conduct a junior olympics in physical education classes. Include such events as the 100 metre dash, or a shotput event in which the distances are measured in metres. Chart the results.

5. Use the metric units in your spelling and reading activities.

6. Have students interview their parents or neighbors on how the metric system will affect them.

7. Plan a bulletin board display with the theme, "Think Metric."

8. Play the role of a radio announcer announcing any sport using the metric system.

9. On an outline map of the world, identify the areas that use the metric system.

10. Go through old magazines. Cut out ads in which the metric system is used.

11. Have the students give weather forecasts using metric units.

12. Have some of your students (and their mothers) bake peanut butter cookies using the following recipe:

CRISP PEANUT BUTTER COOKIES
(Metric Volume Measurement of Ingredients)

240 millilitres margarine
240 millilitres peanut butter
240 millilitres sugar
240 millilitres firmly packed light brown sugar
2 large eggs, beaten
600 millilitres unsifted flour
5 millilitres baking powder
5 millilitres baking soda
5 millilitres salt
5 millilitres vanilla

Stir together margarine, peanut butter and sugars until blended. Beat in eggs and vanilla. Stir together flour, baking powder, baking soda and salt. Add to peanut butter mixture, stirring until well blended. If necessary, chill dough until it can be handled easily. Shape into 2.5 centimetre balls. Place about 5 centimetres apart on a greased baking sheet. Flatten with tines of floured fork making crosswise patterns.

Bake in 176°C (350°F) oven 12 to 15 minutes or until lightly browned.

Yield: About 75 (5 centimetre) cookies.

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SOURCES OF METRIC TEACHING MATERIALS

Cambosco, Inc.
342 Western Avenue
Boston, Massachusetts 02135

Central Instrument Company
900 Riverside Drive
New York, New York 10032

Central Scientific Company
2600 S. Kastner Avenue
Chicago, Illinois 60628

Creative Publications
P. O. Box 10328
Palo Alto, California 94303

Dick Blick
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Galesburg, Illinois 61401

Houghton Mifflin Company
Boston, Massachusetts 02107

Metric Aids
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Toronto 530
Ontario, Canada

Metric Information Office
National Bureau of Standards
Washington, D.C. 20234

Sargent-Welch Scientific Company
35 Stern Avenue
Springfield, New Jersey 07081